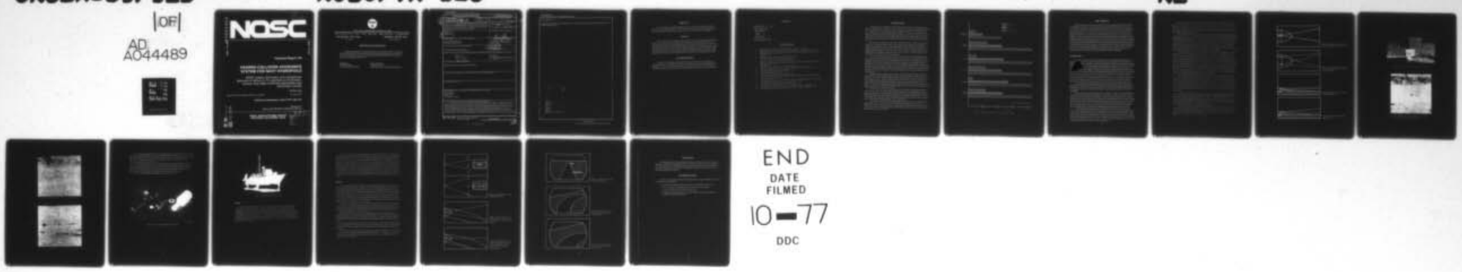
AD-A044 489 NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CALIF F/G 17/7
HAZARD-COLLISION AVOIDANCE SYSTEM FOR NAVY HYDROFOILS (NOSC SYS--ETC(U)
JUN 77 C K BOROUGH

UNCLASSIFIED NOSC/TR-125 NL

1 OF 1

AD
A044489



END
DATE
FILMED
10-77
DDC

(12)

ADA044489

# NOSC

NOSC / TR 125

NOSC / TR 125

Technical Report 125

# HAZARD-COLLISION AVOIDANCE SYSTEM FOR NAVY HYDROFOILS

NOSC system illuminator is an inexpensive approach to active LLLTV; geometry of illuminator, camera, and target minimizes backscatter and maximizes contrast

CK Borough

10 June 1977

Approved for public release; distribution is unlimited

Research and Development, January 1975 to May 1977

Prepared for
NAVAL SEA SYSTEMS COMMAND (SEA 03)

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

RR GAVAZZI, CAPT, USN
Commander

HOWARD L BLOOD, PhD
Technical Director

## ADMINISTRATIVE INFORMATION

Work was performed under Program Element 62712N, Project F12152, Task Area SF12152401 (NOSC F238), by members of the Electro-Optics Division for the Naval Sea Systems Command. This report covers work from January 1975 to May 1977 and was approved for publication 10 June 1977.

Released by
FM Tirpak, Head
Sensor Technology Division

Under authority of
RE Shutters, Head
Surface/Aerospace Surveillance Department

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER 14 NOSC/~~Technical Report 125~~ TR-125 | 2. GOVT ACCESSION NO. 9 Research | 3. RECIPIENT'S CATALOG NUMBER and development technical rep |
| 4. TITLE (and Subtitle) 6 HAZARD-COLLISION AVOIDANCE SYSTEM FOR NAVY HYDROFOILS (NOSC system illuminator is an inexpensive approach to active LLLTV; geometry of illuminator, camera, and target minimizes backscatter and maximizes contrast. | | 5. TYPE OF REPORT & PERIOD COVERED R&D, January 1975 to May 1977 |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) 10 C.K. Borough | | 8. CONTRACT OR GRANT NUMBER(s) 16 17 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center San Diego, California 92152 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62712N, F12152, SF12152401 (NOSC F238) |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command (SEA 03) | 11 | 12. REPORT DATE 10 June 1977 |
| | | 13. NUMBER OF PAGES 16 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 19p. | | 15. SECURITY CLASS. (of this report) Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electro-optics
Hazard avoidance
Illuminators
Low-light-level television

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Navy hydrofoils and other fast ships are threatened by small targets in the water which are normally no hazard at all to larger, slower ships. In collisions with a ship traveling faster than 40 knots, debris such as logs and poles and objects such as buoys are hazards. Over the past several years, several organizations have been developing hazard-collision avoidance systems. Some of these systems, while effective, are expensive. Others, while affordable, are marginally effective. Under a developmental contract with NAVSEA 03 NOSC has been developing an approach to this problem which promises both low cost and maximum effectiveness. This report reviews several past approaches. It covers the present NOSC approach and presents pictorially the results of those portions of (Cont)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102 LF 014 6601

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

393 159

(Cont from block 20)

the approach for which there are functioning models to test. It also discusses parts of the approach which are still in the developmental stage.

## OBJECTIVE

Test and evaluate existing low-light-level sensor systems to determine their practicality for use as collision-avoidance devices aboard Navy hydrofoil craft. Develop improved systems which will be capable of providing advance warning of hazards to navigation.

## RESULTS

Passive and active low-light-level television, direct-view, and forward-looking infrared systems were tested on an oceanographic tower and aboard a Navy hydrofoil craft. The only system found effective against small targets on the surface was the active low-light-level television system. This system was found to be too expensive to procure and operate. A new system was designed and constructed and improved illuminators were constructed to NOSC specifications. Tested at sea, the improved system was effective against low-contrast targets and provided information to the right and left of the swath of water traversed by the ship.

## RECOMMENDATIONS

On ships to be equipped with hazard-collision avoidance systems, installation is recommended of (1) a sensitive, low-light-level television sensor, (2) three continuous-wave illuminators, (3) a servo loop between the sensor and the ship's helm, and (4) a display to indicate the path of the ship during dead-ahead flights and maneuvers to port and starboard.

## CONTENTS



## ILLUSTRATIONS

## INTRODUCTION

During the past several years, the Naval Ocean Systems Center tested many low-light-level sensor systems. As many as eight sensors have been tested simultaneously aboard an oceanographic tower. In addition, passive low-light-level television (LLLTV) systems, direct-view devices, forward-looking infrared (FLIR) systems, and active LLLTV systems have been evaluated aboard Navy hydrofoils and other fast ships such as US Coast Guard surface-effect vessels (hovercraft) and Navy planing craft. These night-vision devices have been evaluated for application as navigation aids, surveillance aids, and collision-avoidance systems.

For purposes of this report, the term "collision avoidance" refers to the avoidance of collision with relatively large targets such as other ships. In the areas of navigation, surveillance, and collision avoidance, many night-vision systems which have been proven valuable were found during the testing. Another area in which sensors are used is termed "hazard-collision avoidance." This term refers to the avoidance of collision with relatively small targets such as logs floating in the water, buoys, and debris of various descriptions. This latter area is the main concern of this report.

Few of the tested systems were found to be fully effective against small floating targets. A wet, brown log, for example, presents very low visual contrast against the water and is difficult to detect with any of the passive LLLTV systems. Even when such logs are marginally detectable, they appear as a shade of grey against another, slightly different shade of grey, the water. In such cases, the target, although technically judged visible, does not draw attention to itself and is likely not to be noticed. The FLIR devices were found to perform in a somewhat improved manner both with respect to the range at which detection was first possible and with respect to the contrast against the water, but performance was marginal at best.

The only systems which were found to be effective against small targets were the active LLLTVs. Using gating techniques to reduce backscatter, these systems displayed a marked increase in the contrast of targets against water returns. The contrast was found so high, in many instances, that the targets appeared as white objects against a black background. Much of the illumination hitting the water was reflected away from the sensor; most of the illumination hitting the target was reflected back to be received by the sensor. Figure 1 is a bar chart showing the detection distances which have been realized against low-contrast targets by the various system types.

Active LLLTV systems, however, have always exhibited two important shortcomings. The cost of such a system is approximately triple that of a passive LLLTV and the logistics requirements are much greater. Cooling of the GaAs laser illuminators is required and an 80-pound dewar of liquid nitrogen, used for this purpose, lasts for only 6 or 7 hours of operation. Navy hydrofoils, with 5- and 6-day missions, cannot, from a practical standpoint, carry sufficient liquid nitrogen to meet system needs.

Conclusions reached from the testing program are that there are two basic system types which cannot meet the requirement for collision avoidance (passive LLLTV and FLIR) and only one system type which is capable of meeting the requirement but which is too expensive to procure and operate and which is highly problematic considering existing logistics practices (active LLLTV).

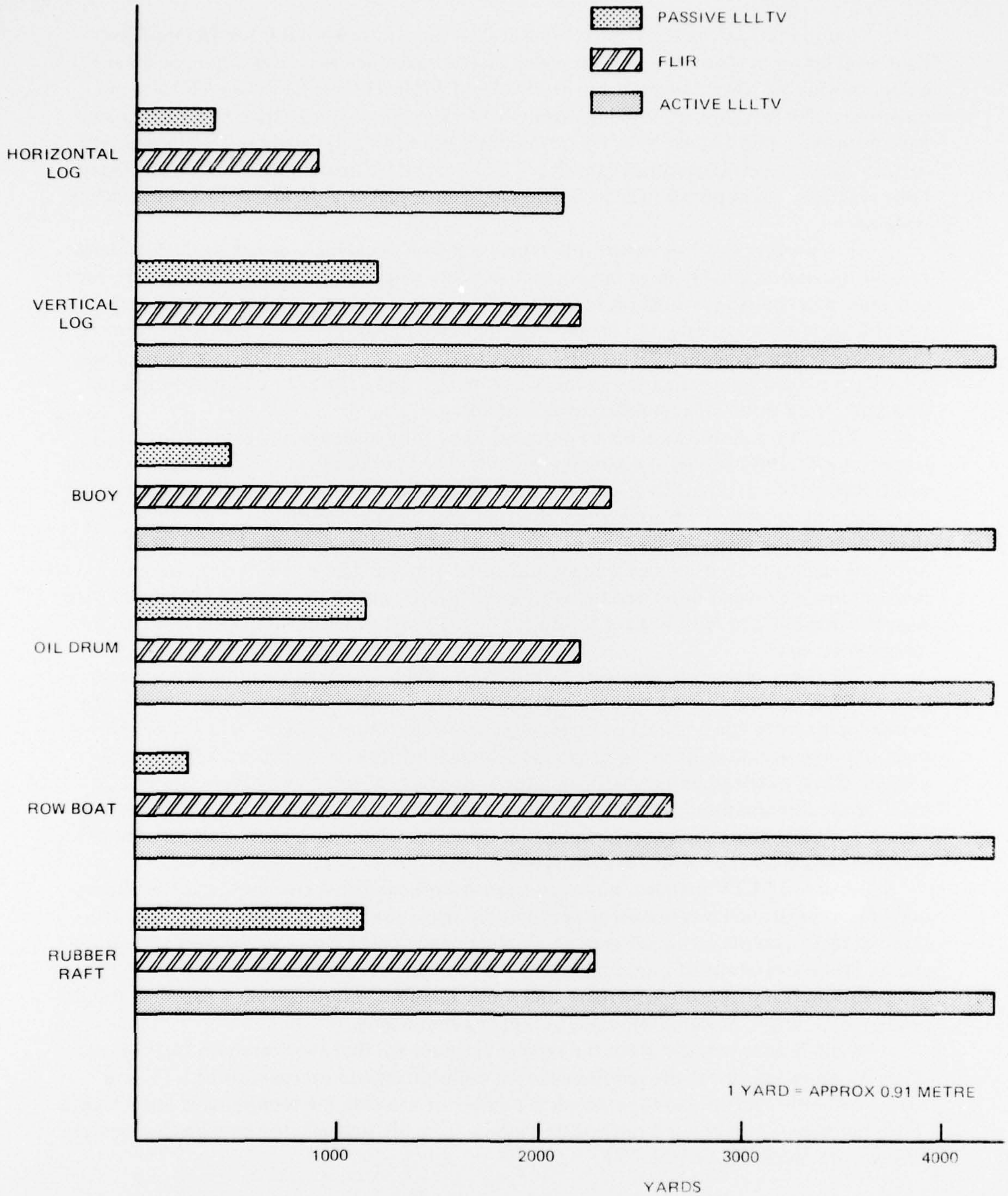



Figure 1. Detection ranges of various targets using various sensors.

## NOSC APPROACH

The Naval Ocean Systems Center, at present, is recommending three improvements to the night-vision system to be used aboard Navy hydrofoils. Since the recent testing of state-of-the-art equipments for night vision showed that an active LLLTV is the most promising of all the systems, the NOSC approach envisions the use of such a system. The goal of the NOSC approach is to retain some of the key advantages of an active LLLTV system while, at the same time, lowering the cost and logistics requirements. To meet this goal, in addition to test and evaluation, there has been an ongoing developmental program to make changes and improvements in the system. An active LLLTV system which is inexpensive and which presents virtually no logistics problems has resulted from this effort. This is discussed under the heading of ILLUMINATOR. A second system improvement attacks the problem of resolution versus field of view. A servo is recommended to effect this improvement and is discussed under the heading of SERVO. A third improvement is related to just what targets are actually within the intended flight path and what maneuvers will be required. This improvement recommendation is discussed under the heading of SWATH.

## ILLUMINATOR

The active LLLTV system is one which incorporates an illuminator to provide supplemental illumination of targets. This illuminator can be anything from a flashlight to a highly specialized laser. Supplemental artificial illumination provides two distinct advantages over [illegible]ive system. First, extra photons are provided when light levels are too low for the se[illegible] of the sensor. Second, because the illuminator is aimed at a grazing angle to the w[illegible] directly at the targets of concern, the contrast of targets against the water background is much enhanced. Much of the illumination falling upon the water at a grazing angle is reflected away from the sensor while some of the illumination reaching the targets is reflected directly back to the sensor. Targets appear white and the water black. Contrast is even further enhanced by filtering the illuminator and the sensor so that only some specific band of wavelengths is used. This makes the sensor insensitive to much of the ambient light which would otherwise provide photon return from both the target and the water.

Use of supplemental illumination, however, has one disadvantage. If there is any particulate moisture in the area (such is the usual case just over the ocean), light from the illuminator is scattered and some returns directly to the sensor. This backscatter problem is one parameter which can be solved only by the use of illuminators which are not merely searchlights.

Gated systems have been developed which separate, in time, the outgoing illumination from the returning reflected illumination at the sensor. A pulse of photons is emitted while the sensor is turned off electronically. As this pulse travels away from the ship, the sensor remains off until such time as the photons are returning from the target area. Photons which returned earlier by reflection from water droplets in the near field were not received since the sensor was off. After the turned-on sensor receives the protons from the target area, it is again turned off, a new pulse is sent out, and the process repeats. The result is that, at the CRT, only the target area is displayed and backscatter is greatly reduced.

A searchlight which can be turned on and off effectively at the very fast rates required for this gating technique is not a simple device. It is expensive and usually involves a laser system which requires cryogenic cooling. Also, the sensor must incorporate a somewhat complex electronic system so that it can be turned on and off at fast rates in synchronism with the illuminator off and on cycles. Logistics become complex. The cooler becomes either a cumbersome closed-cycle system or a tank of expendable liquid nitrogen, 80 pounds of which lasts only for about 6 or 7 hours of operation.

Another way to achieve some improvement in backscatter reduction is to use an ordinary (cw) searchlight for illumination but to separate it from the sensor so that the illumination beam does not cross the field of view of the sensor until it is out in the vicinity of the target area. During the recent testing period, several attempts were made to effect this advantage by spatial separation. The results were discouraging because of an error which was consistently a part of our approach.

Figure 2 shows a top view of a ship with a sensor and illuminator mounted together on the pilot house. The area contributing backscatter is the whole field of view since both the illuminator and the sensor cover the same area. Figure 3 shows the same ship but with the sensor and illuminator separated as far as possible atop the pilot house. In the near field, there is an area which does not contribute backscatter. Even though this area is relatively small, the improvement is somewhat significant because backscatter is worst in the near field. If the separation could be increased several times the distance shown, the backscatter would be reduced to acceptable levels. This, however, would involve complex cantilevered mounts or the mounting of the sensor on one ship and the illuminator on another.

The other option, of course, is to separate the sensor and the illuminator in a vertical plane with the sensor high and the illuminator low. During the tests, this approach was always rejected because the separation available by such mounting still did not provide as much separation as did the horizontal mounting atop the pilot house. This approach presented an additional problem; in order for the illuminator to be mounted low, it had to be mounted far forward in order that its beam not be intercepted by the deck. When the illuminator was far forward and the sensor was on the pilot house, the two devices and the target area were virtually in line. This seemed to limit the effective spatial separation even beyond that indicated by the actual vertical separation. Figure 4 illustrates this method of mounting. The spatial separation appears minimal. Some of these assumptions made during consideration of vertical mounting are incorrect and the approach which has produced marked success does indeed use vertical separation to great advantage.

The new arrangement is shown in figure 5. There is no reason to illuminate above the water as the targets of interest for hazard-collision avoidance are all floating targets. (There may possibly be subsurface targets, but avoidance of collision with these is not part of this system.) There is also no reason to attempt to look below the surface with the sensor; it cannot see into the water in any event. There is also no reason to look at the water in front of the ship, for, if a target is first detected in this area, there will be insufficient time for maneuvering. With these facts in mind, there is no disadvantage in the geometry shown in figure 5 and the resulting overlap of sensor and illuminator is minimal. Backscatter is greatly reduced.

To test this new geometry, a special illuminator with careful beam shaping and filtering was developed and constructed under contract by the Westinghouse Company. The illuminator was then tested at sea on PEGASUS (PHM 1) with a Westinghouse LLLTV. Figure 6 shows the installation of the camera at the bow of PEGASUS. Figure 7, obtained with this system, shows a brown cardboard box more than 700 yards (640 metres) distant. Dimensions of the box were approximately 2.5 by 1 by 1 feet (75 by 30 by 30 centimetres). The contrast is very high in the photograph.

Figure 8 shows the same target with the illuminator turned off. The box is barely visible and, for all practical purposes, is judged invisible as it would not be noticed in real time. Another example of the visibility which can be obtained with the illuminator is shown in figure 9. The material is kelp floating on the water. During tests of the system, any debris floating on the water was seen in similar contrast.

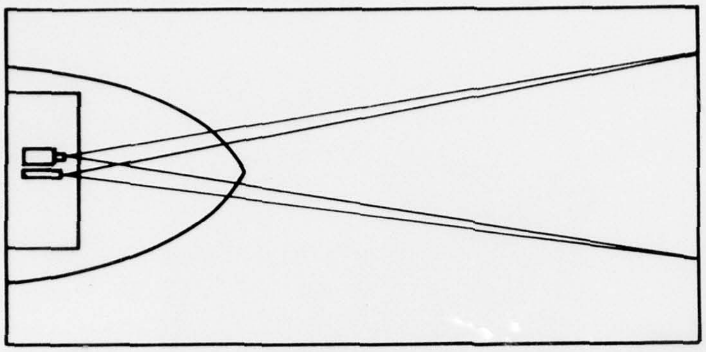


Figure 2. Illuminator and sensor mounted adjacent to each other on the pilot house.

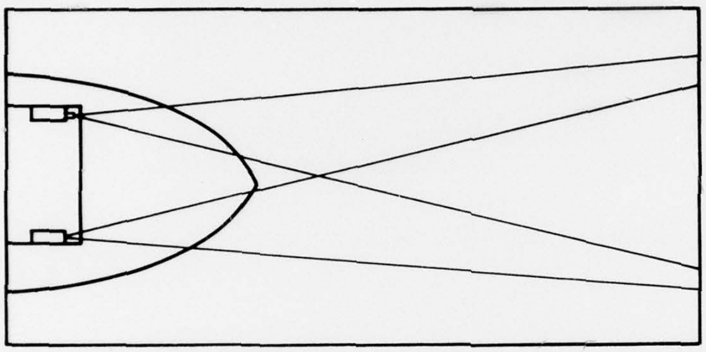


Figure 3. Illuminator and sensor mounted atop the pilot house but with maximum horizontal separation.

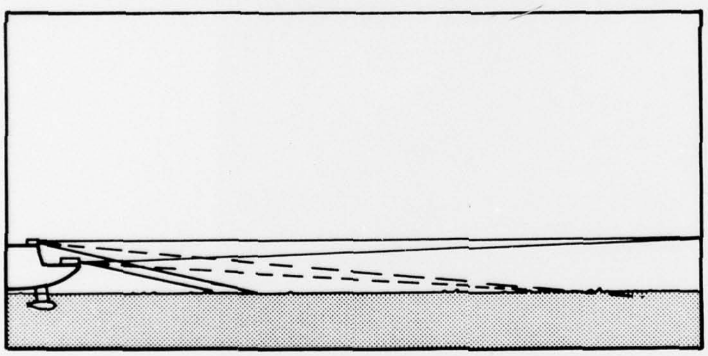


Figure 4. Illuminator and sensor directed to cover the same area.

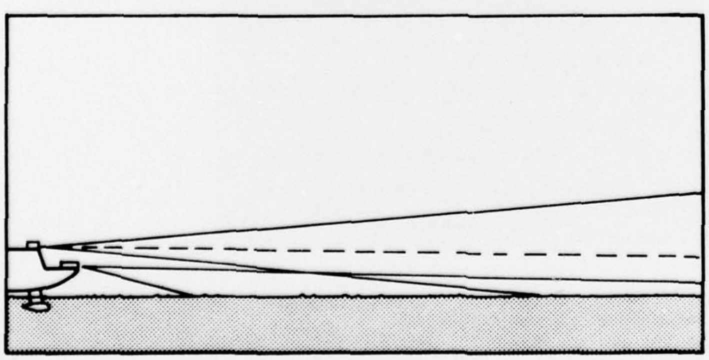


Figure 5. The new geometry of sensor and illuminator.

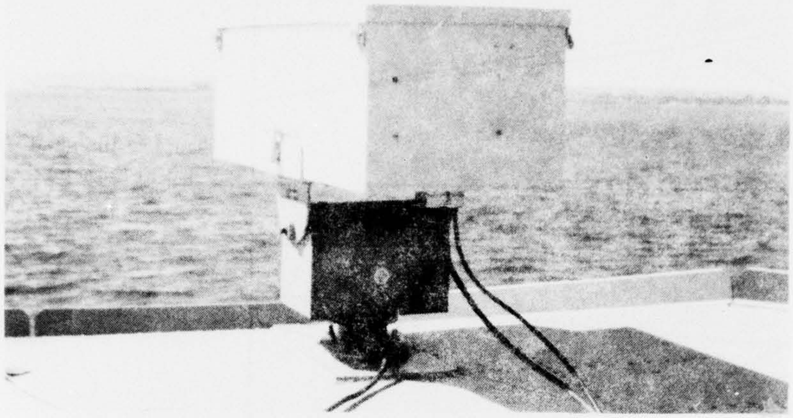


Figure 6. Camera as mounted on PEGASUS during testing.

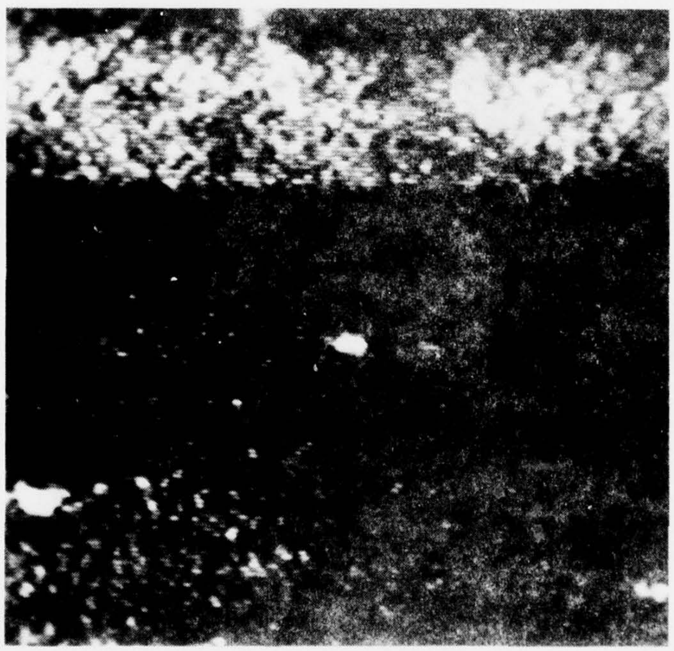


Figure 7. CRT presentation showing a target at approximately 700 yards (640 metres) with the illuminator on.

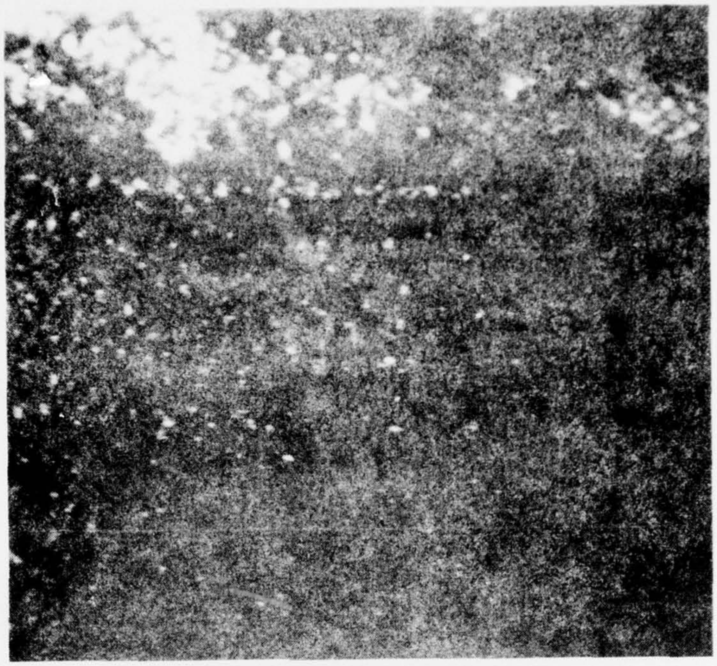


Figure 8. The same target (as in fig 7) with the illuminator off.

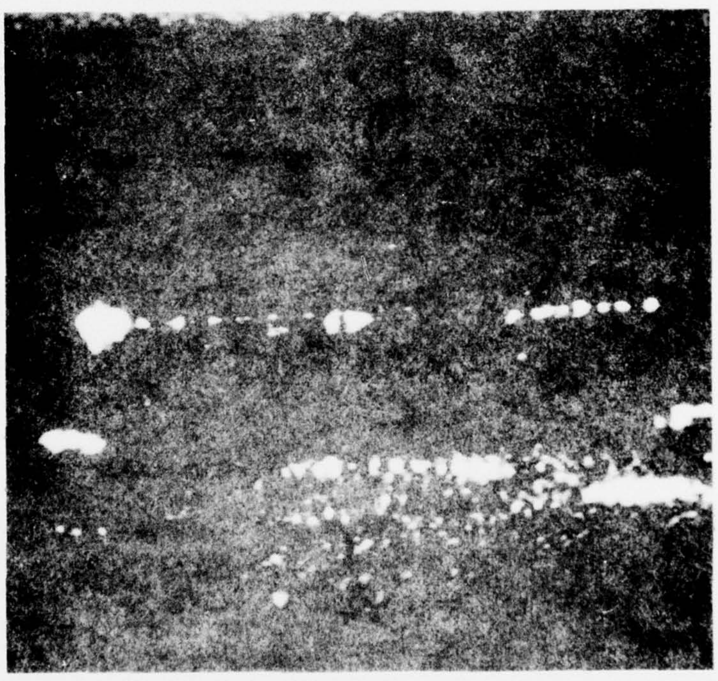


Figure 9. CRT presentation of kelp in the field of view of the *sensor and illuminator.*

Three additional illuminators have been fabricated at NOSC. Figure 10 is one of these before assembly. It is planned to use these aboard PEGASUS in company with a new sensor now being purchased. The three illuminators will be mounted so that they will cover a wide field of view in front of the ship. This method will preclude the need for a servo loop between the illuminator and the sensor.

In operation, the illuminators are filtered so that very little visible light is allowed to pass. The cutoff is about 0.75 micrometres with shorter wavelengths not passing. There is still a slightly visible pink glow if one looks directly into the illuminator from within the field of view. With more drastic filtering at 0.8 micrometres or longer, the effectiveness of the LLLTV sensor is lessened, as its sensitivity falls off sharply in this area.

The test ship, USS PEGASUS (PHM-1) is shown in figure 11.

LSF 1798-9-76

Figure 10. One of three illuminators built at NOSC.

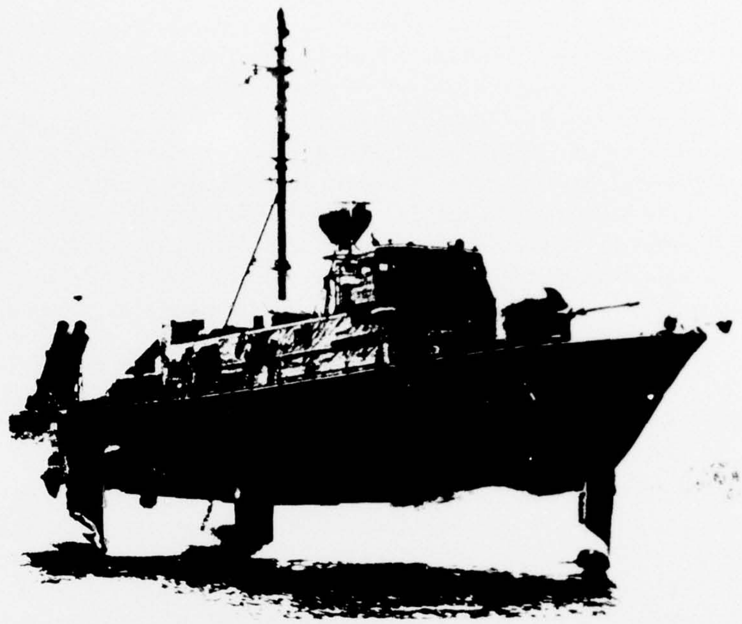


Figure 11. USS PEGASUS used in the tests.

**SERVO**

One of the critical tradeoffs to be made in developing hydrofoil hazard-collision avoidance systems is that between resolution and field of view. As the field of view is widened, the resolution becomes less. A 40-degree field of view in front of the ship is a comfortable one as it gives sufficient information to port and starboard of the ship to allow turn maneuvers. At 40 degrees, however, the resolution characteristics are marginal. With a 20-degree field of view, the resolution is adequate but the view to port and starboard is unsatisfactory. Both fields of view are shown in figure 12 together with the resulting CRT display for a given log target.

If a servo were to be incorporated between the sensor and the helm so that when the ship was to begin a turn the sensor would also turn in the same direction, certain advantages of a narrower field of view could be retained while still gaining the advantages of a wider field of view. For example, if a 20-degree field-of-view lens was to be used and the servo was designed to turn the sensor up to 10 degrees to port and starboard, the resolution characteristics of a 20-degree sensor could be maintained at all times while the total surveyed area in front of the ship would be 40 degrees. Of course, the field of view at any one time would be only 20 degrees, but this would be the area of maximum interest. A servo system such as this would greatly improve the tradeoff situation between coverage and resolution. Figure 13 shows the coverage of the ship's path when a turn to starboard is made with a 20-degree field of view and no servo. Figure 14 is a presentation of the same maneuver using the servo system.

## SWATH

It is sometimes difficult to determine just by viewing a monitor screen whether the ship is moving straight ahead or is making a turn. Of greater importance is the difficulty of determining whether a target appearing on the screen is a collision hazard to the ship, particularly if the target is some distance away and the ship is in a turn. The target may appear to the right of the monitor screen and yet be far to the left of the path the ship will follow in the turn. It may also seem to be in a safe position and yet be right on a collision course. To resolve these difficulties, it would be advantageous to have a representation at the monitor of the water over which the ship is adjusted to pass. The operator would understand this presentation to be the "roadway" of the vessel.

Consider a monitor overlay such as presented in figure 15. If the ship is proceeding directly ahead, the triangular area coming to a point at the horizon is the roadway, or the water surface over which the ship will pass. The foils of the hydrofoil will cut directly down these lines if the helm is not adjusted to port or starboard. If a log should appear between the two lines, it would be on a collision course.

When the helm is repositioned, the two straight lines no longer represent the true roadway, which is now curved instead of straight. Figure 16 shows a portion of the roadway of immediate interest for a turn to starboard. The roadway is centered somewhat on the monitor because of the action of the servo between the helm and the sensor as described earlier.

The lines which indicate the roadway on the monitor would bend to the right and left as the ship maneuvered to starboard and to port. These lines must be electronically defined and generated by other circuits. They are not part of the video information derived from the sensor.

If there were no servo between the helm and the sensor, the monitor image when the ship was turning to starboard would be that shown in figure 17. This image is unacceptable, as there is insufficient information on conditions to the right of the roadway and hazards could be present in that area.

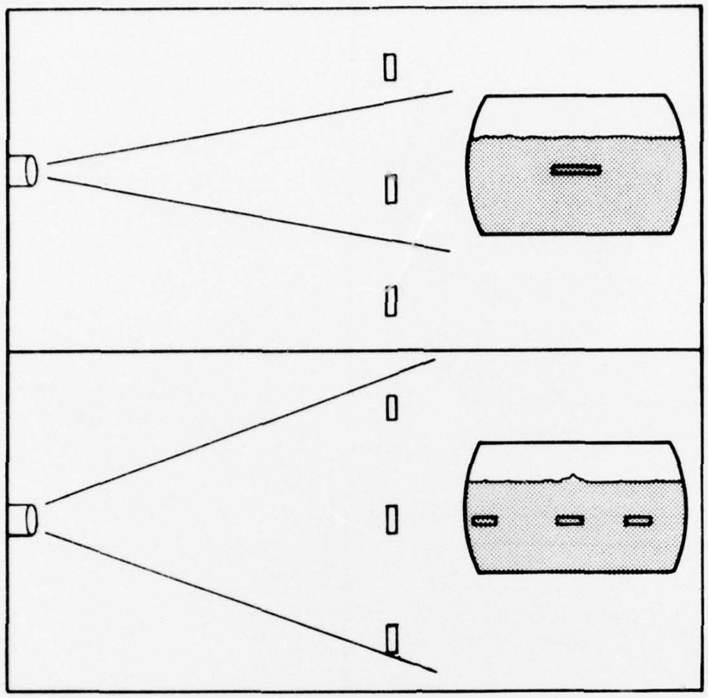


Figure 12. CRT images with 20- and 40-degree fields of view.

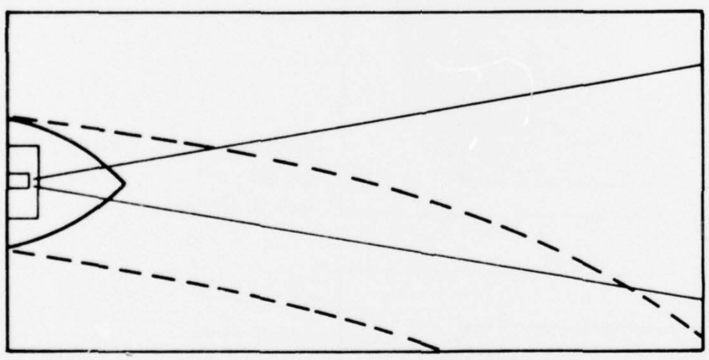


Figure 13. Sensor coverage of the flight path with a 20-degree field of view and no servo during a starboard maneuver.

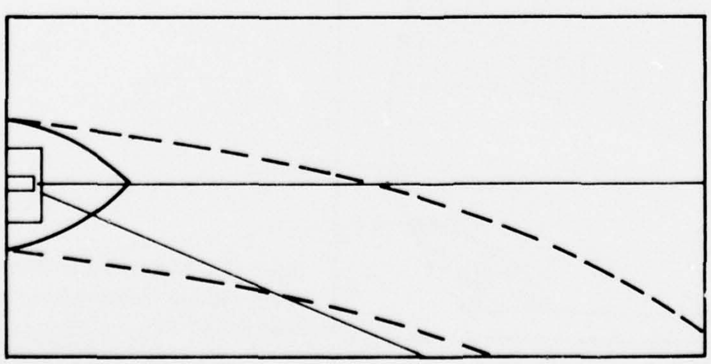


Figure 14. The same field of view (fig 13) but using a servo installed between the helm and sensor to provide an extra 10 degrees of area to starboard.

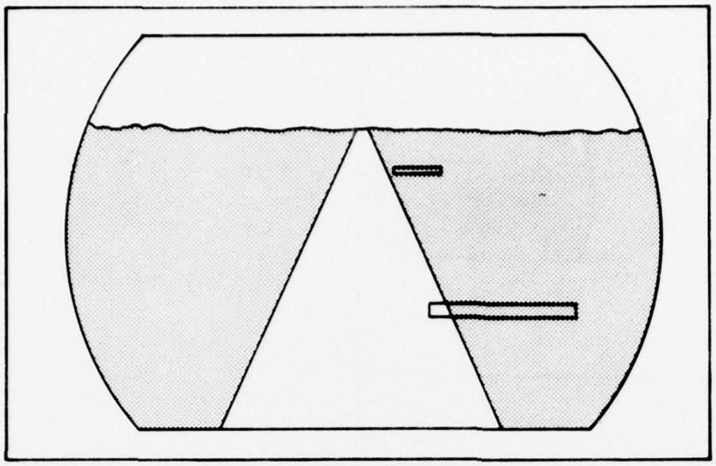


Figure 15. Triangular area through which the ship will travel.

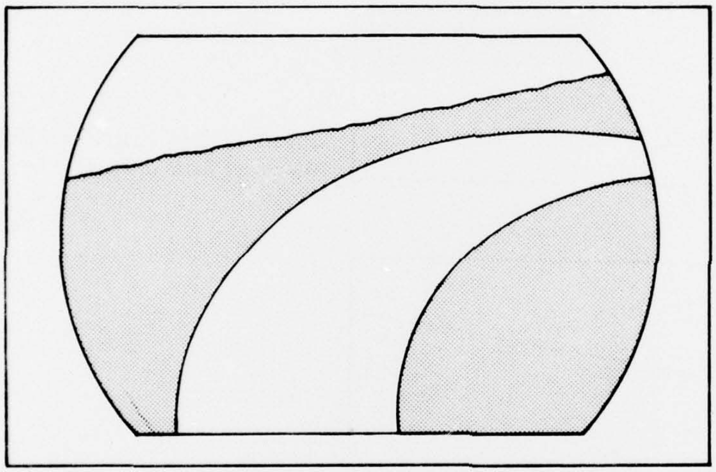


Figure 16. Curved lines representing the path of the ship during a turn to starboard.

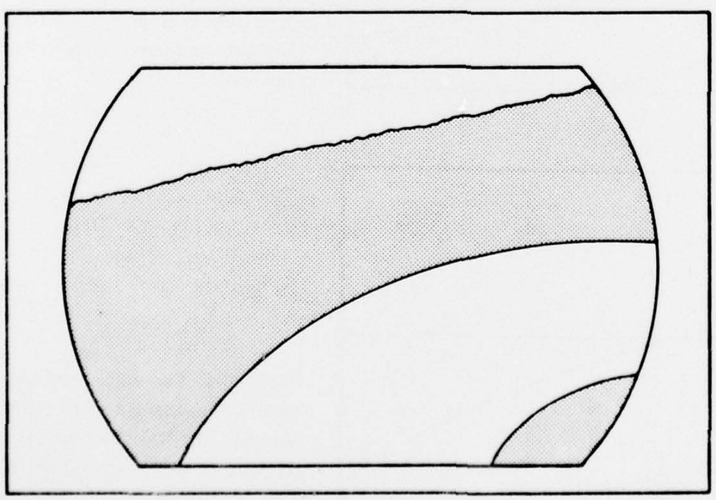


Figure 17. Noncentering of the swath without the servo between helm and sensor.

## CONCLUSIONS

The NOSC approach to hazard-collision avoidance is an inexpensive one which has been proven effective by comparison with more costly gated systems. It provides high contrast with normally low-contrast targets and provides information to the right and left of the swath of water to be covered. It locates targets in context with ship's course and also provides rough range information.

## RECOMMENDATIONS

On ships to be equipped with hazard-collision avoidance systems, NOSC recommends the inclusion of the following:

1. A sensitive low-light-level television sensor, either an ISIT or an I-Isocon.
2. Three continuous-wave illuminators with filters and beam shaping.
3. A servo loop between the sensor and ship's helm.
4. A display indicating the actual path of the ship during dead-ahead flight and maneuvers to port and starboard.